AN ANALYSIS OF DISTRIBUTION PATTERNS

OF AMPHIBIANS AND REPTILES IN TEXAS

APPROVED:

Major Professor

Minor Professor

Director of the Department of Biology

Dean of the Graduate School

AN ANALYSIS OF DISTRIBUTION PATTERNS OF AMPHIBIANS AND REPTILES IN TEXAS

THESIS

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Cuyler Hershey Leonard

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CHAPTER I

INTRODUCTION

Background

Ruthven (1908) indicated several well-defined biological regions of North America which he stated have been known by naturalists from the time of the Pacific Railroad Surveys. He named these regions according to their plant types, even though he considered each region to have specific plant and animal species. Vestal (1914) used the term "biotic province" for areas with distinctive plants and animals.

Dice (1943) defined twenty-nine North American Provinces, including seven in Texas. His goal was to delimit provinces by use of a general survey of vegetation types, ecological climax, flora, fauna, climate, physiography, and soil. Unfortunately, the fauna was of minor importance in Dice's definitions. Bailey (1905) attempted the first such classification for Texas, mapping the life zones of the state. However, the life-zone concept is based upon temperature and ignores other ecological factors. It is a useful concept in mountainous areas with vertical zonation, but of limited value over broad geographic areas. Blair (1950) redefined Dice's (1943) biotic provinces in Texas, by using topographic features, climate, vegetation types, and terrestrial vertebrates exclusive of birds. He recognized three major biotas which influence the Texas fauna: the Sonoran (Chihuahuan and Navahoian Provinces), the Austroriparian (Austroriparian Province), and the Neotropical (Tamaulipan Province).

According to Blair, the central part of the state is a large ecotone which is composed of three provinces. The Texan Province is a westward dispersal route for Austroriparian species. The Balconian Province represents a climatic barrier to limit western species from an eastward extension. The Kansan Province is considered a grassland and transitional area. Throughout this region there is a general intermingling of representatives of the three biotas.

Smith (1949) pointed out that there was no agreement among authors as to what constitutes the size and form of a biotic province. He suggested the use of a mathematical method of biotic province definition as the best solution to this problem. Webb (1950) used similarity values based upon ranges of snakes and mammals to determine biogeographic regions of Texas and Oklahoma. According to Peters (1955), this method may indicate adjacent areas with a high faunal similarity but does not indicate boundaries between regions, because of the step-wise loss of species from the fauna, rather than an abrupt loss.

Hagmeier and Stults (1964) devised an objective method of calculating province boundary values. However, the final determination is subjective, and may be relevaluated at a later time (Hagmeier, 1966).

Statement of Problem

The purpose of this investigation was to analyze the distribution of amphibians and reptiles in Texas by means of the methods of Webb (1950), and Hagmeier and Stults (1964). An additional graphic analysis was made, including ranges and range limits. This analysis provides a cross-section of faunal change along selected base lines across the state. These data then were compared to the biotic provinces of Texas (Blair, 1950).

Sources of Data

The ranges for individual species of amphibians and reptiles were determined from range map studies prepared by Raun (unpublished). A few species, which have been reported from Texas, have been omitted from the analyses. Plethodon cinereus has its center of distribution in the east, but according to Conant (1958), there are questionable endemic references to this species in far east Texas. Since the validity of these records is quite doubtful P. cinereus was omitted. According to Conant (1958), Hemidactylus turcicus, the Mediterranean Gekko is an old-world species introduced into port cities. It is not a native species and will not be considered further. Because of taxonomic confusion, unreliable literature records, and inadequate sampling, the ranges of one half of the turtles in Texas are impossible to approximate with any confidence. To avoid excessive bias, all turtles have been omitted. Insufficient range data on the single Texas member of the Order Crocodila, Alligator mississipiensis, make the species inappropriate for inclusion in this paper.

Range limits were drawn to correspond to county lines on a Texas county map of 1-inch-to-100-mile scale. Range limits incorporate museum and literature references, with the exception of those records that appear to be outside the ranges of these species and are considered questionable.

Several species were omitted in calculating the similarity values and the index of faunistic change values (Chapter II), because of taxonomic problems.

There are several species of salamanders which must be given special consideration. There are two literature references from Nacogdoches and Jasper Counties, according to Raun (unpublished), of _Ambystoma talpoideum_. This species has its center of distribution in the east, and ranges from the eastern two-thirds of Louisiana to the Atlantic (Conant, 1958). The absence of intermediate records indicates that the Texas populations may be isolates, rather than westward extensions. _Ambystoma talpoideum_ does not aid in defining province boundaries, and was omitted from the subsequent calculations.

The seven nominal species of endemic, neotenic salamanders found on the Edwards Plateau have been considered together rather than separately. This was done to reduce undue influence of relatively localized edaphic factors, even though this lumping may tend to reduce the distinctiveness of the Balconian Province.

There are several members of the Order Anura which must be considered. According to Raun (unpublished), there are literature records of _Bufo americanus_ from Cook, Grayson, and Fannin Counties, where this toad extends into Texas along the Red River. However, this is a minimal extension of a wide-spread range through the United States and Canada. This minimal extension into Texas, which complicates rather than aids in the defining of biogeographic areas, was disregarded.

There are several members among the reptilian Order Squamata which need special consideration. Five species of the Suborder Lactertilia (Lizards) were omitted from similarity values and index of faunistic change calculations while a special note was made of one other species.

According to Raun (unpublished), Coleonyx reticulatus is found only in Brewster County, Texas. Furthermore, this species is not included in the general range studies by Conant (1958) and Stebbins (1966). C. reticulatus appears to be related to the Mexican species C. elegans. If so, it is a small extension into the Big Bend country and is of no value in defining biogeographic areas of Texas.

Museum specimens from Culberson and Jeff Davis Counties of Phynosoma douglassi, and museum specimens from Winkler and Ward Counties of Sceloporus graciosus probably represent disjunct populations of western species. On the other hand, museum records from Culberson County of Eumeces multivirgatus indicate a minimal extension of another western species into Texas. These disjunct Texas populations and the minimal extension into Texas complicate rather than aid in defining biogeographic areas, and are not considered in the similarity values and index of faunistic change calculations.

Cnemidophorus scalaris, which has been recorded from Presidio and Brewster Counties, is a problem, for both taxonomic and distributional reasons. This species is omitted from range studies by Conant (1958) and Stebbins (1966). Therefore, C. scalaris will be omitted from similarity values and index of faunistic change calculations.

Finally, several species of the Suborder Serpentes (Snakes) are not included in the similarity values and index of faunistic change evaluations of biogeographic regions of Texas. According to Raun (unpublished), Carphophis amoenas is found only in Bowie County. The known range was extended into Red River County in the spring of

1967, when this species was found by a North Texas State University collecting group near Boxelder, Texas. This is an eastern species making a minimal extension into Texas and is not considered in the biogeographic region calculations.

Opheodrys vernalis and Storeria occipitomaculata are species with their center of distribution in the east. Each of these species is represented in Texas by disjunct populations in the eastern one-third of Texas. There are two disjunct populations of Cemophora coccinea along the Texas coast. This species also has its center of distribution in the east. The disjunct Texas populations of the above three species are not included in the subsequent similarity values and index of faunistic change calculations.

Two species of the Genus Tantilla will be omitted from biogeographic region calculation because of limited known Texas ranges. Tantilla cucullata is a secretive, rare snake. According to Raun (unpublished), it is recorded in the literature as being found only in Brewster County. An additional specimen from Jeff Davis County is in the North Texas State University collection.

Tantilla diabola is known from only three specimens from Val Verde County. The taxonomic status of both species is in doubt. Both have been omitted from this study.

Pituophis melanoleucas is represented in Texas by two distinctly separate populations: a large western population and a very small eastern population. The small eastern population, P. m. ruthveni, is found mainly in Louisiana and is not included in the biogeographic region evaluations. The typical bullsnake, P. m. sayi, covers the western two-thirds of Texas. It has a very distinctive range limit and is retained for biogeographic region evaluations.

CHAPTER II

METHODS AND MATERIALS

Fauna Used

This paper includes a working fauna of 4 Orders, 65 Genera, and 167 Species. Distributional maps of the reptiles and amphibians, as indicated in the introduction, were used.

Size and Pattern of Ranges

It has been pointed out by Sokal and Sneath (1963) and Hagmeier and Stults (1964) that two conditions must be considered in order to determine biogeographic regions: first, some range limits must occur within the specified locality, and second, the range limits must be clumped into some pattern. A single overlay map was sketched to determine if a general clumping of range limits occurred within Texas.

The range in Texas of each individual species under consideration was determined by using a polar planimeter. The range in square miles was converted to diameters of circles, to better visualize the numerical values and to compare this data with literature records. The diameter miles of each species are placed in the second column of Table 1.

Mapping of Areas

Two methods of statistical analysis which have been used to determine the biogeographic areas were employed in the study. The first method was devised by Webb (1950), and includes the following steps:

TABLE 1--Amphibian and Reptile Fauna Considered Within Texas. This table includes species center of distribution, species range within Texas, and species occurring within a province. Abbreviations for Center of Distribution include E eastern, W western, P plains, S southern, WS widespread, and EN endemic. Texas range is given in diameter-miles, as explained in text. Species are considered here to occur in a province if they have one-quarter their total range in the province, or if they are present in at least one-quarter of its area, or if they are endemic to it.

			Biotic Provinces					
	Center of Distribution	Texas Range in Diameter-miles	Austroriparian	Texan	Tamaulipan	Balconian	Kansan	Chihauhaun
	1	2	3	4	5	6	7	8
Salamanders								
Necturus maculosus	E	143	x					
Siren intermedia	E	331	x	x	x			
Ambystoma maculatum	E	109	x					
Ambystoma opacum	E	170	x					
Ambystoma talpoideum	E	61	x					
Ambystoma texanum	E	319	x	x				
Ambystoma tigrinum	E	566	x	x	x		x	x
Notophthalamus meridionalis	EN	126			x			
Notophthalamus viridescens	E	282	x	x	x			
Amphiuma means	E	154	x					
Desmognathus fuscus	E	143	x					
Plethodon glutinosus	E	136	x					
Eurycea neotenes	EN	149				x		
Eurycea latitans	EN	1				x		
Eurycea nana	EN	1				x		
Eurycea troglodytes	EN	1				x		
Eurycea pterophila	EN	1				x		
Eurycea quadridigitatus	E	194	x	x				
Typhlomolge rathbuni	EN	1				x		

Table 1--continued

	1	2	3	4	5	6	7	8
Frogs								
Scaphiopus bombifrons	P	342			x		x	x
Scaphiopus couchi	S	426		x	x	x	x	x
Scaphiopus hammondi	W	378					x	x
Scaphiopus holbrooki	E	347	x	x	x			
Leptodactylus labialis	S	64			x			
Eleutherodactylus augusti	EN	153				x		
Syrrhophus campi	S	54			x			
Syrrhophus marnocki	EN	216				x		x
Bufo americanus	E	70		x				
Bufo cognatus	W	306					x	x
Bufo debilis	W	492		x	x	x	x	x
Bufo houstonensis	EN	103		x	x			
Bufo marinus	S	70			x			
Bufo punctatus	W	475		x	x	x	x	x
Bufo speciosus	S	507		x	x	x	x	x
Bufo valliceps	S	377	x	x	x	x		
Bufo woodhousei	WS	566	x	x	x	x	x	x
Acris crepitans	E	544	x	x	x	x	x	x
Hyla arenicolor	W	133						x
Hyla baudini	S	61			x			
Hyla cinerea	E	333	x	x	x			
Hyla crucifer	E	207	x					
Hyla squirella	E	178	x	x				
Hyla versicolor including *H. chrysoscelis*	E	368	x	x	x	x		
Pseudacris clarki	P	401		x	x	x	x	
Pseudacris streckeri	P	323	x	x				
Pseudacris triseriata	E	279	x	x				
Gastrophryne carolinensis	E	289	x	x				
Gastrophryne olivacea	P	478	x	x	x	x	x	x
Hypopachus cuneus	S	135			x			
Rana areolata	E	173	x	x				
Rana catesbeiana	E	489	x	x	x	x	x	x
Rana clamitans	E	241	x	x				
Rana grylio	E	74	x					
Rana palustris	E	195	x					
Rana pipiens	WS	566	x	x	x	x	x	x
Lizards								
Coleonyx brevis	W	265			x			x
Coleonyx reticulatus	EN	78						x
Anolis carolinensis	E	324	x	x	x			

Table 1--continued

	1	2	3	4	5	6	7	8
Crotaphytus reticulatus	EN	126			x			
Crotaphytus collaris	W	450		x		x	x	x
Crotaphytus wizlizenii	W	190						x
Phrynosoma cornutum	P	566	x	x	x	x	x	x
Phrynosoma douglassi	W	78						x
Phrynosoma modestum	S	346					x	x
Sceloporus cyanogenys	S	147			x			
Sceloporus grammicus	S	67			x			
Sceloporus graciosus	W	58					x	
Sceloporus magister	W	210						x
Sceloporus merriami	S	166						x
Sceloporus olivaceus	S	393		x	x	x		
Sceloporus poinsetti	W	271				x		x
Sceloporus undulatus	WS	566	x	x	x	x	x	x
Sceloporus variabilis	S	200			x			
Urosaurus ornatus	W	309			x	x		x
Uta stansburiana	W	277					x	x
Eumeces anthracinus	E	129	x					
Eumeces brevilineatus	S	343			x	x		x
Eumeces fasciatus	E	283	x	x				
Eumeces laticeps	E	261	x	x				
Eumeces multivirgatus	W	60						x
Eumeces obsoletus	P	483		x	x	x	x	x
Eumeces septentrionalis	P	260	x	x				
Eumeces tetragrammus	S	67			x			
Lygosoma laterale	E	403	x	x	x	x		
Cnemidophorus inornatus	W	228						x
Cnemidophorus gularis	S	557		x	x	x	x	x
Cnemidophorus exsanguis	W	162						x
Cnemidophorus sexlineatus	E	457	x	x	x		x	
Cnemidophorus tesselatus	W	254					x	x
Cnemidophorus tigris	W	218						x
Cnemidophorus scalaris	S	60						x
Holbrookia lacerata	P	261			x	x		
Holbrookia maculata	W	387		x			x	x
Holbrookia propinqua	S	174			x			
Holbrookia texana	W	429		x	x	x	x	x
Gerrhonotus liocephalus	S	168				x		x
Ophisaurus attenuatus	E	356	x	x	x			
Snakes								
Leptotyphlops dulcis	W	506		x	x	x	x	x
Leptotyphlops humilis	W	211						x
Arizona elegans	W	476		x	x	x	x	x
Carphophis amoenas	E	60	x					

Table 1--continued

	1	2	3	4	5	6	7	8
Cemophora coccinea	E	89			x			
Coluber constrictor	WS	416	x	x	x		x	
Coniophanes imperialis	S	58			x			
Diadophis punctatus	WS	518	x	x		x	x	x
Drymarchon corais	S	220			x			
Drymobius margaritiferus	S	44			x			
Elaphe guttata	P	529		x	x	x	x	x
Elaphe obsoleta	E	434	x	x	x	x		x
Elaphe subocularis	W	203						x
Farancia abacura	E	235	x	x				
Ficimia cana	W	307				x	x	x
Ficimia olivacea	S	107			x			
Virginia striatula	E	355	x	x		x		
Virginia valeriae	E	249	x	x		x		
Heterodon nasicus	P	495		x	x	x	x	x
Heterodon platyrhinos	E	425	x	x	x	x	x	
Hypsiglena ochrorhyncha	W	309		x	x	x	x	x
Lampropeltis calligaster	E	348	x	x			x	
Lampropeltis doliata	WS	436	x	x	x	x	x	x
Lampropeltis getulus	WS	446	x	x	x	x	x	x
Lampropeltis mexicana	S	196				x		x
Leptodeira septentrionalis	S	90			x			
Masticophis flagellum	WS	566	x	x	x	x	x	x
Masticophis taeniatus	W	336			x	x		x
Natrix cyclopion	E	160	x	x				
Natrix erythrogaster	E	494	x	x	x	x	x	x
Natrix grahami	E	307	x	x			x	
Natrix harteri	EN	69					x	
Natrix rhombifera	E	430	x	x	x	x	x	
Natrix rigida	E	200	x					
Natrix fasciata	E	292	x	x				
Opheodrys aestivus	E	232	x	x	x	x		
Opheodrys vernalis	E	89		x				
Pituophis melanoleucus	WS	506	x		x	x	x	x
Rhinocheilus lecontei	W	480		x	x	x	x	x
Salvadora grahamiae	W	209						x
Salvadora hexalepis	W	112						x
Salvadora lineata	S	296		x	x	x		
Sonora episcopa	P	574		x	x	x	x	x
Sonora semiannulata	W	103						x
Storeria dekayi	E	177	x	x	x	x		
Storeria occipitomaculata	E	77	x					
Tantilla cucullata	EN	119						x
Tantilla diabola	EN	72						x
Tantilla gracilis	P	436	x	x	x	x		
Tantilla nigriceps	W	471			x	x	x	x
Tantilla planiceps	W	220						x

Table 1--continued

	1	2	3	4	5	6	7	8
Thamnophis cyrtopsis	W	251				x		x
Thamnophis marcianus	W	503		x	x	x	x	x
Thamnophis proximus	E	505	x	x	x	x	x	x
Thamnophis radix	P	115					x	
Thamnophis sirtalis	WS	342	x	x			x	
Trimorphodon vilkinsoni	W	113						x
Tropidoclonion lineatum	P	301	x	x		x		
Micrurus fulvius	E	390	x	x	x	x		
Agkistrodon contortrix	E	436	x	x	x	x		x
Agkistrodon piscivorus	E	413	x	x	x	x		
Sistrurus catenatus	P	513		x	x	x	x	x
Sistrurus miliarius	E	260	x	x				
Crotalus atrox	W	528		x	x	x	x	x
Crotalus horridus	E	323	x	x				
Crotalus lepidus	S	227				x		x
Crotalus molossus	W	249				x		x
Crotalus scutulatus	W	147						x
Crotalus viridis	W	360					x	x

1) Texas range maps were prepared for each amphibian and reptile species.

2) A transparent plastic map with a numbered 100-mile-square grid of sampling areas was prepared.

3) A species-occurrence chart was prepared, and each species with a range including at least one-third of each 100-mile-square area was counted.

4) A similarity value (SV) was calculated, based on the formula,

$$SV = \frac{C \times 100}{T}$$

where C is equal to the number of species which occur within both of the adjacent sample areas, and T is equal to C plus the number of species which occur within either but not both adjacent sample areas. The resultant values are graphed.

5) Regions with similarity values of 75 or more were contoured and indicated by shading.

6) The procedure was repeated with the use of a 50-mile-square grid of sampling areas.

The second method used was that of Hagmeier and Stults (1964), and includes the following steps:

1) The range maps prepared for the similarity values analysis were used.

2) A transparent overlay map with a numbered 50-mile-square grid of sampling areas was prepared.

3) An index of faunistic change (IFC) was computed for each of the 50-mile-square areas according to the formula,

$$IFC = \frac{100\ L}{n}$$

where L is equal to the range limits within a specified 50-mile-square area and n is equal to all species which occur within a specified 50-mile-square area, i.e., including ranges and range limits.

4) Indexes of faunistic change values were changed to numerical values of 1 through 8, as indicated by Table 2.

Table 2 -- Adjustment of Index of Faunistic Change (IFC) Values.

Raw IFC Values	Adjusted IFC Values
1-4	1
5-9	2
10-14	3
15-19	4
20-24	5
25-29	6
30-34	7
35-40	8

5) The adjusted values were plotted on an outline Texas Map, and those areas of the map with adjusted index of faunistic change values of 1-4 were shaded.

6) Biogeographic boundaries were determined by contouring adjacent index of faunistic change values of 8.

Graphic Analysis

The four orders of herptiles under consideration were organized into four groups, including (1) Order Trachystomata and Order Caudata (Sirens and Salamanders), (2) Order Anura (Frogs and Toads), (3) Order Squamata, Suborder Lacertilia (Lizards), and (4) Order Squamata, Suborder Serpentes (Snakes). Furthermore, each of the groups was subdivided into eastern, southern, plains, western, and widespread categories, based on the geographic centers of distribution. The center of distribution of each species is indicated in Column 1 of Table 2.

Texas maps were prepared for each of the distributional categories within a herptile group (i.e., eastern anurans, western lizards, etc.). For each of the herptile species, a range boundary line was drawn on the Texas map corresponding to its group and center of distribution. Graphic descriptions of the delimited animal populations were constructed, as follows:

1) Cross-sections prepared through a significant number of biotic provinces were drawn, joining various extremities of the state.

2) A graph was constructed for each cross-section. These graphs give the number of individual species found at each point on the cross-section and indicate the geographic centers of distribution of each species.

3) For reference, the biotic provinces of Texas, as determined by Blair (1950), are indicated on the graphs. Furthermore, each species range within the biotic provinces is indicated in Columns 3 through 8 of Table 2.

CHAPTER III

RESULTS

Range Analysis

The first condition established by Sokal and Sneath (1963) concerning range limits within a specified area has been met. The ranges of the amphibians and reptiles vary from 566 diameter miles to 44 diameter miles, excluding the 6 specific endemic cave salamanders (_Eurycea latitans_, _E. nana_, _E. troglodytes_, _E. pterophilia_, _Typhlomolge rathbuni_, and _T. tridentifera_). Five species had statewide distributional ranges, and the average range covered 49 percent of the state.

The distributional patterns show a tendency to group themselves when placed on a single transparent plastic overlay map. This grouping tendency shows up as high index of faunistic change values. Observation reveals that these high values form definite contiguous distributional lines. Therefore, the second condition of Sokal and Sneath (1963) concerning contiguous range limits has been met.

Mapping Analysis

Analysis of similarity values (Webb, 1950) reveals very definite regions of high faunal similarity. The similarity value represents the percentage of species common to two 100-mile-square sample blocks. The similarity values range from a high of ninety-nine to a low of fifty-six, and the average value is seventy-seven. According to Webb (1950), areas with similarity values of 75 or more are included within a biogeographic region. His method calls for the construction of two separate maps based on east--west (horizontal) and north--south (vertical) values, respectively. Finally, these drawings are superimposed to form one drawing. All similarity values are included on Figure 1, which is contoured to include values of seventy-five or more. Areas which represent biogeographic regions are shaded in blue. This method does not account for the single high value of seventy-seven, which also is contoured.

The biogeographic regions were named by Webb (1950) as the Eastern Forest Community to the east, the High Plains Community to the north, the Trans-Pecos Community to the west, and the Rio Grande Community to the south. A fifth community, noted in central Texas, is termed the Balcones Community.

An attempt was made to calculate similarity values by the use of 50-mile-square units. Similarity values tended to be very high, even though the range between high and low values was similar to that obtained with 100-mile-square units. It is impossible to contour these similarity values.

Application of the analysis method by Hagmeier and Stults (1964) reveals biogeographic regions similar to those of Webb (1950). Additional interpretation may define province boundaries of Texas. The index of faunistic change values indicates the percentage of species whose ranges end within a 50-mile-square area. Therefore, low index of faunistic change values represents regions of faunistic homogeneity, while high values represent regions of faunistic heterogeneity. Furthermore, very high index of faunistic change values may be indicative of province boundaries.

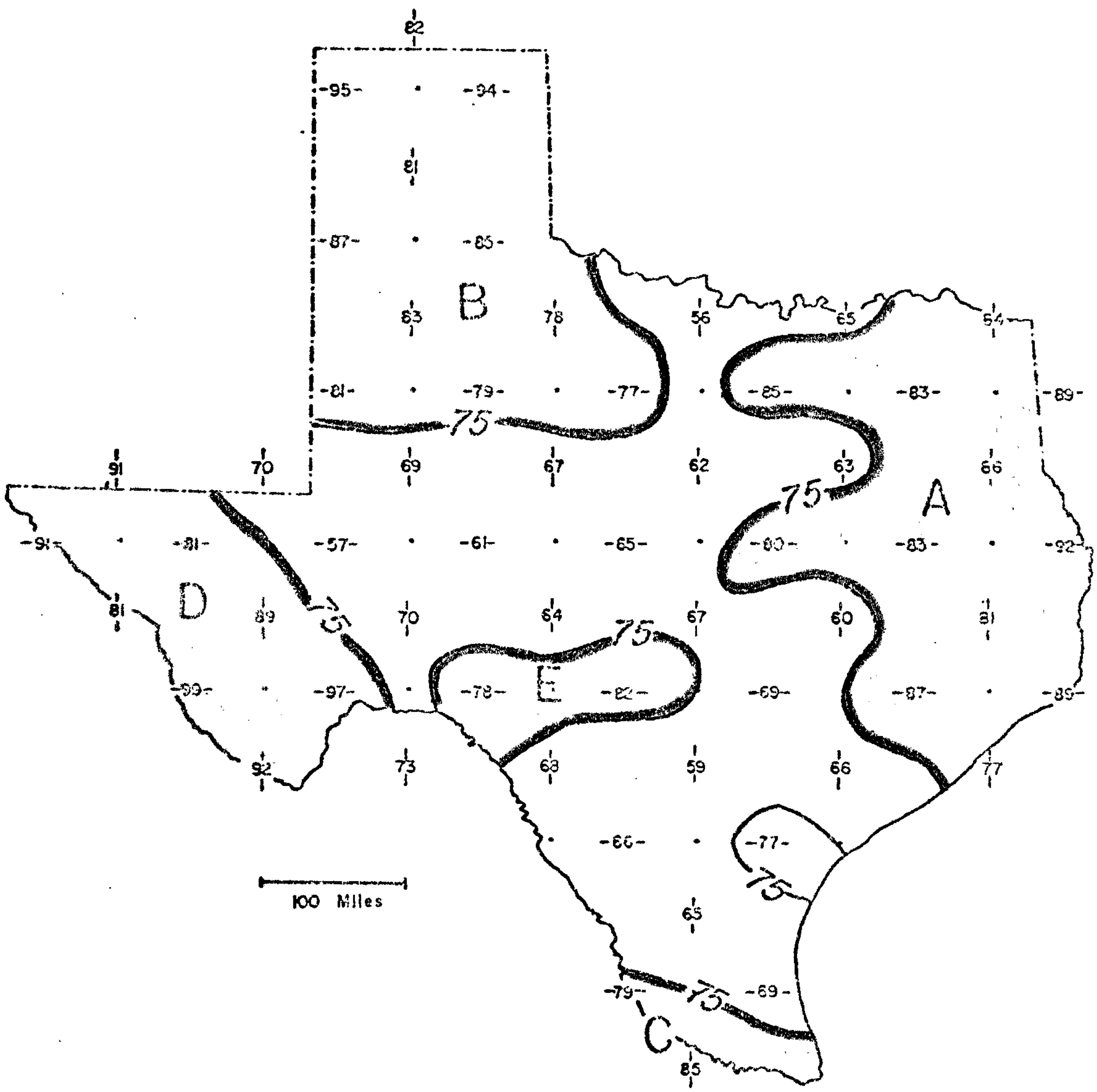

Fig. 1--Faunal similarity values for Amphibians and Reptiles in Texas--Community map regions with similarity values of 75 or more indicated by shading: A-Eastern Forest Community, B-High Plains Community, C-Rio Grande Community, D-Trans-Pecos Community, and E-Balcones Community.

A region map similar to those obtained by using Webb's (1950) method may be demonstrated by use of index of faunistic change values which are given on the 1-to-8 scale. If values 1 through 4 may be considered relatively homogeneous and values 5 through 8 relatively heterogeneous, one may construct a map (Figure 2). On this map the low index of faunistic change values is shaded in blue. Four regions may be designated which are similar to those developed using the similarity values.

Biogeographic provinces of Texas may be determined on the assumption that the highest index of faunistic change values represents the most heterogeneous fauna and, therefore, represents barriers between provinces (Hagmeier and Stults, 1964). A line is used to connect high index of faunistic change values in Figure 3. A very short line is drawn in the northeastern part of the state, along relatively high index of faunistic change values which lie between low index of faunistic change values. Five distinctive amphibian and reptile provinces (Figure 3) may be demonstrated in Texas, and may be named, using Blair's (1950) terminology, as Kansan, Chihuahuan, Balconian, Tamaulipan, and Texan-Austroriparian. These provinces, based on amphibians and reptiles, closely approximate those of Blair (1950), except that the Austroriparian and Texan provinces can be only partially separated. The only evidence of an Austroriparian boundary is the short line in the northeastern part of the state.

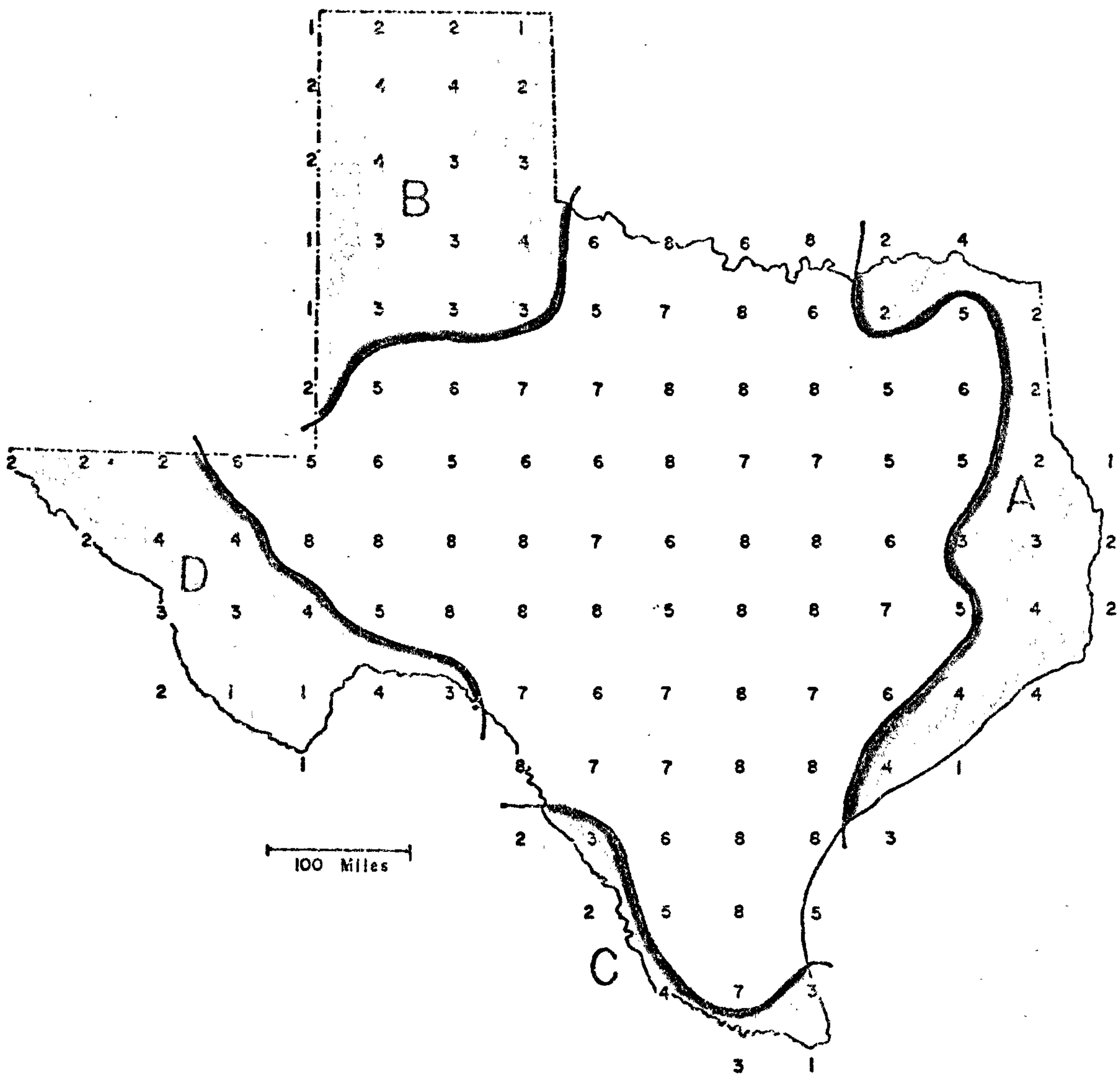

Fig. 2--Index of Faunistic Change Values for Amphibians and Reptiles in Texas: Community Map regions with index of faunistic change values of 4 or less indicated by shading: A-Eastern Forest Community, B-High Plains Community, C-Rio Grande Community, and D-Trans-Pecos Community.

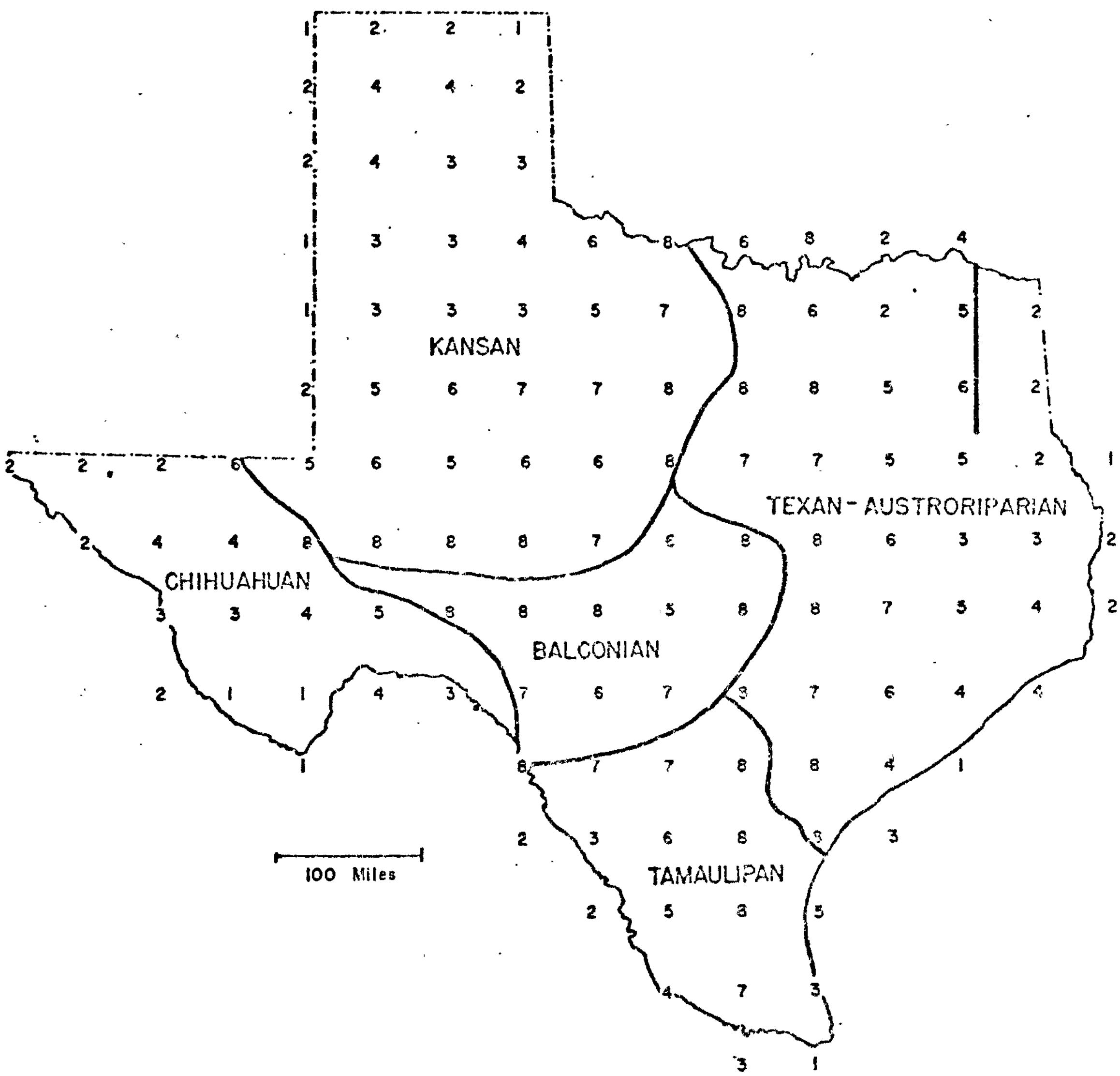

Fig. 3--Index of Faunistic Change Values for Amphibians and Reptiles in Texas: Provinces are determined by contouring values and are named according to Blair (1950).

Graph Analysis

Several interesting observations are made from the cross-sectional graphic analysis of the amphibians and reptiles. These cross-sectional graphic analyses are presented as Figure 4 through 8.

First, similar faunal areas may be observed by comparing these graphs. The Trans-Pecos Community (Chihuahuan Province) is distinguished by having a large number of lizards and snake species with centers of distribution in the west. The Eastern Forest Community (Austroriparian Province) is characterized by a large number of eastern salamanders, frogs, and toads. Several eastern snakes are also found throughout this community. The Rio Grande Plains Community (Tamaulipan Province) is characterized by species whose centers of distribution are in the south. These include species of frogs, lizards and snakes. The High Plains Community (Kansan Province) has few distinguishing species of amphibians and reptiles. It may be considered a community, because it lacks a general grouping of range limits.

Areas with high index of faunistic change values may be seen within the cross-sectional graphic analysis illustrations. Blair's biotic provinces (1950), which correspond very closely to the amphibian and reptile biogeographic provinces as determined by the Hagmeier and Stults (1964) method, are indicated on these graphs. By definition, a large number of range limits determines a high index of faunistic change values, and these high values indicate boundaries of biotic provinces.

The easiest province boundary to distinguish is the eastern edge

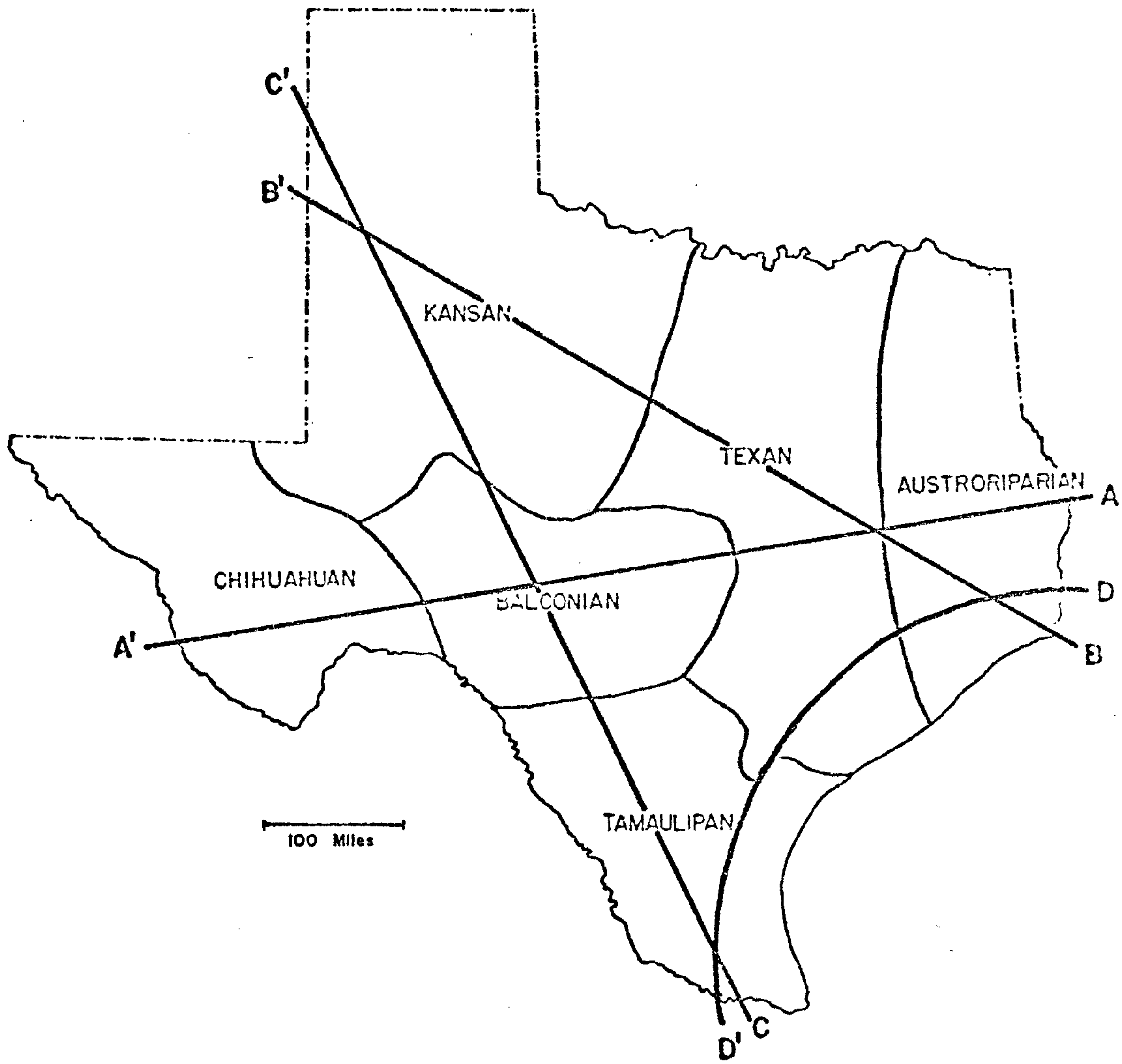

Fig. 4--Reference Map for cross section graphic range analysis. Biotic Provinces are indicated and named after Blair (1950).

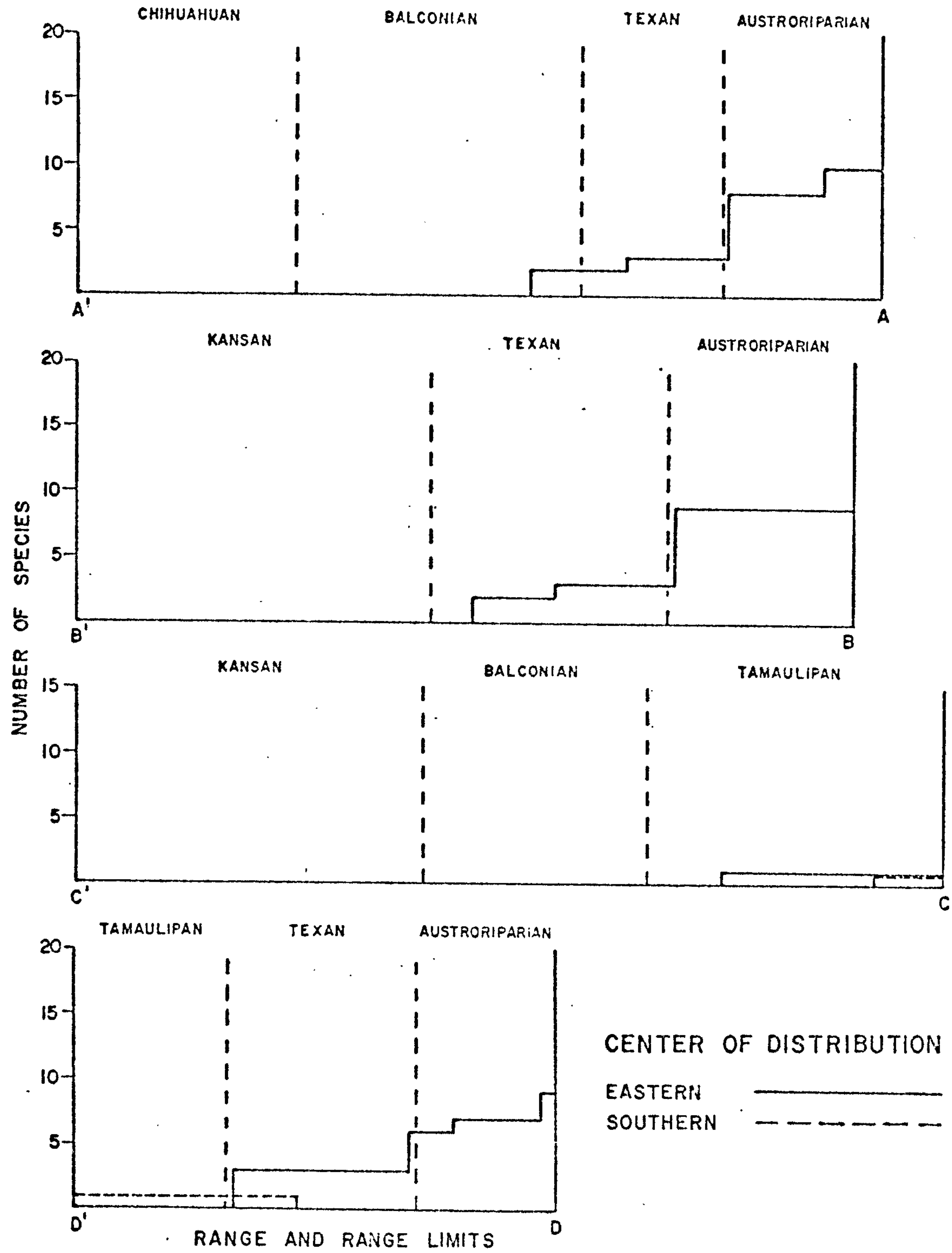

Fig. 5--Cross Section Graph for the Distribution of Salamanders. See figure 4 for reference lines.

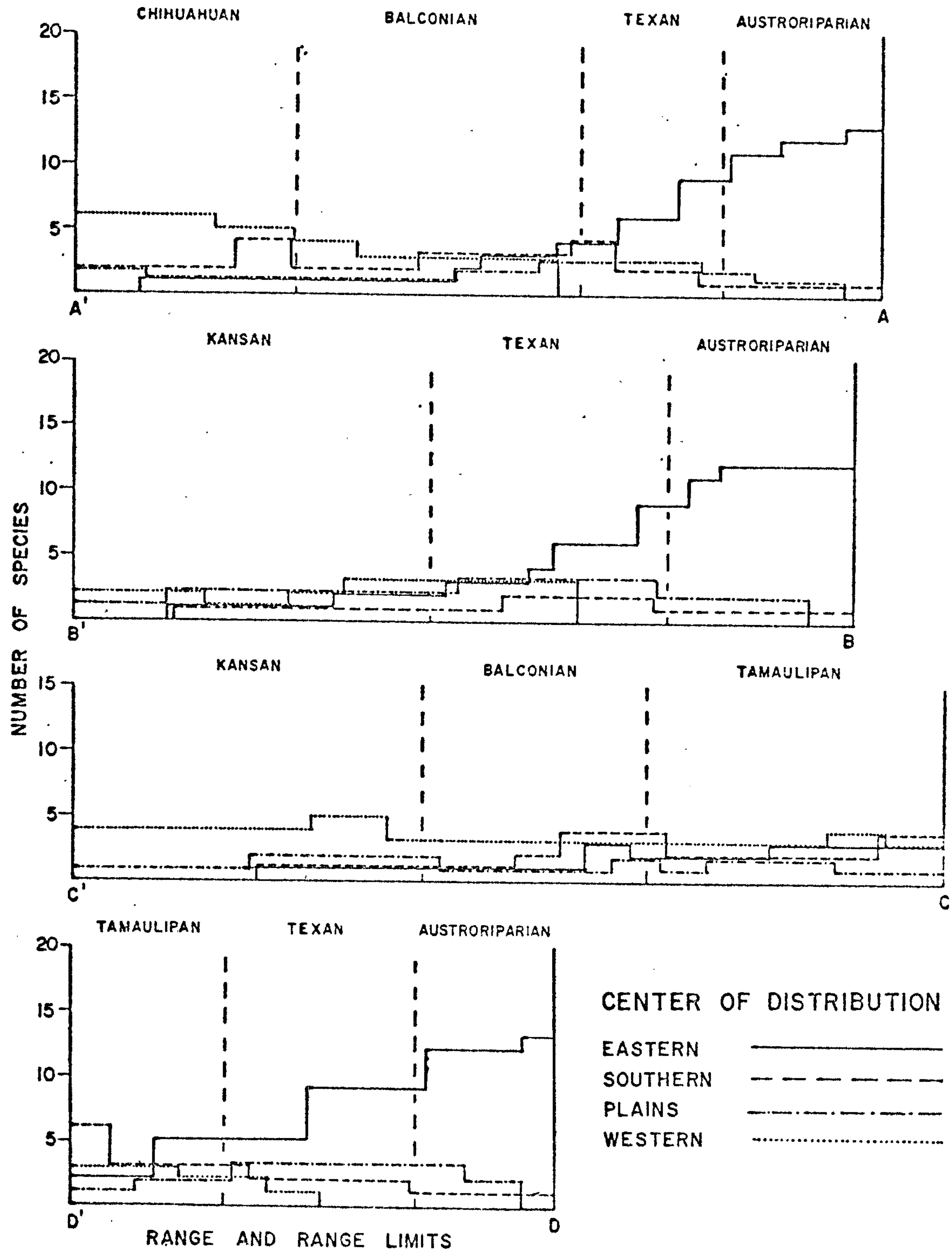

Fig. 6--Cross Section Graph for the Distribution of Frogs and Toads. See figure 4 for reference lines.

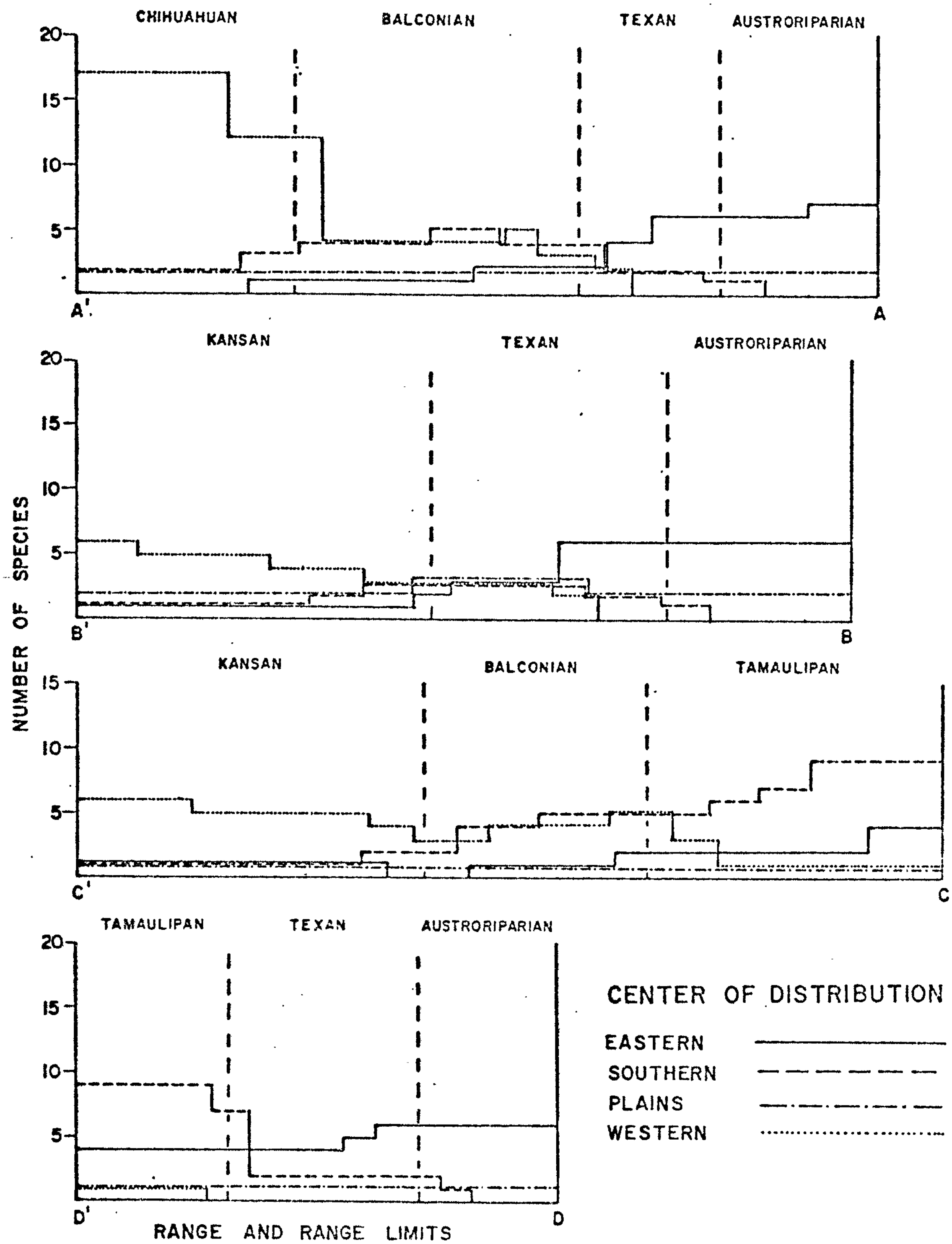

Fig. 7--Cross Section Graph for the Distribution of Lizards. See figure 4 for reference lines.

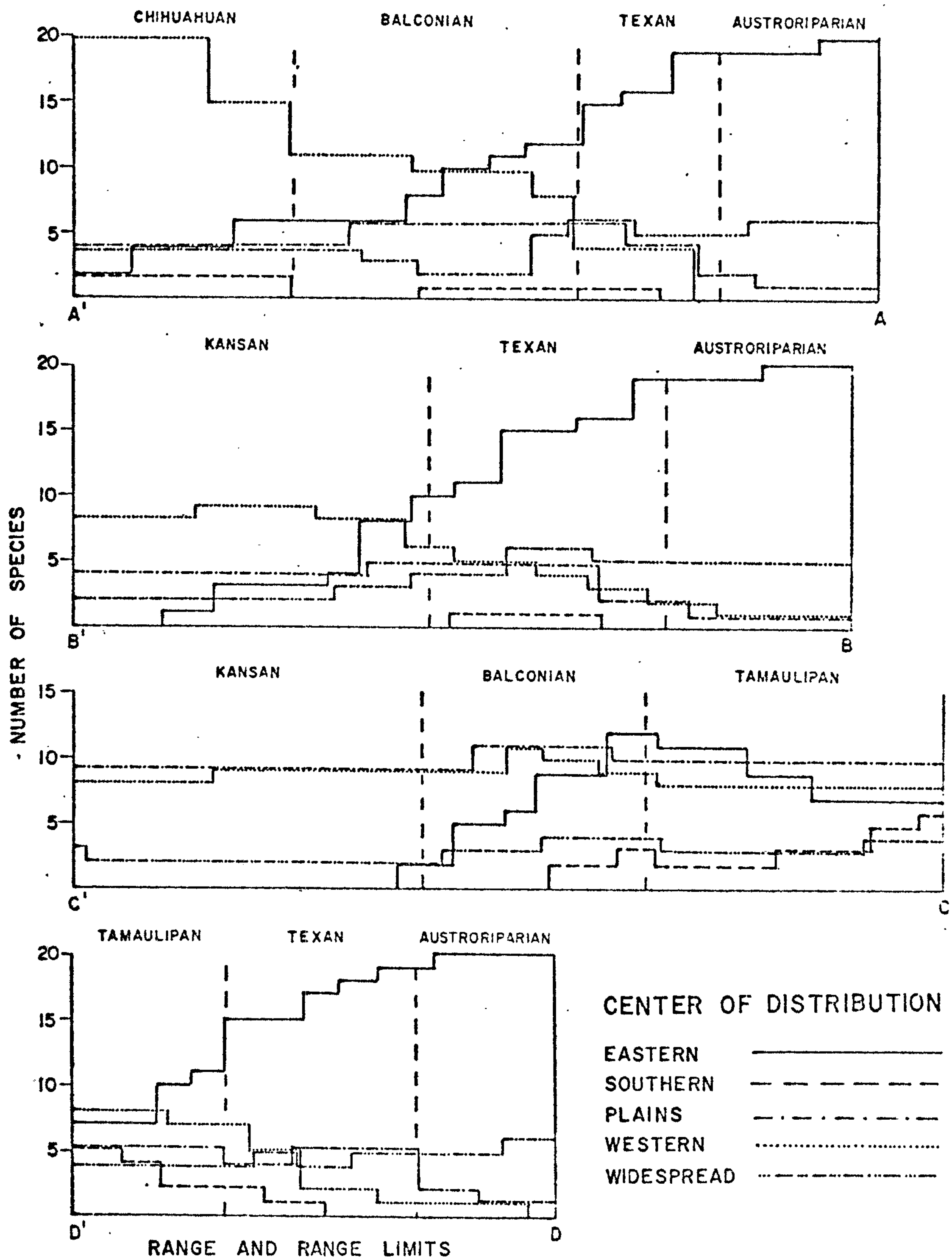

Fig. 8--Cross Section Graph for the Distribution of Snakes. See figure 4 for reference lines.

of the Chihuahuan Province. Twenty-two species of western lizards and snakes have range limits which occur at this boundary, as indicated by A'--A of Figures 7 and 8. In addition, seven other lizard and snake species, whose center of distribution is other than western, occur here. Finally, three frog species have range limits at this boundary along the A'--A cross-section. Therefore, thirty-two species of amphibians and reptiles, excluding the Orders Testudinata and Crocodilia, distinguish the eastern edge of the Chihuahuan Province.

The only group of species within our study which may distinguish a boundary between Blair's Texan and Austroriparian Provinces is the Order Caudata. The graphic analysis indicated that the Texan is a wide boundary area between the Austroriparian Province and the Tamaulipan, Balconian, and Kansan Provinces, to the west.

The range limits which distinguish the Balconian Province are grouped along its boundaries with the Chihuahuan, Kansan, Texan and Tamaulipan boundaries. The graphic analysis of the Orders Anura and Squamata indicates that no one species is a dominant indicator of the boundaries, but that all species contribute to a boundary formation. In fact, the range limits of eastern snake species tend to stair-step across the Balconian Province, as demonstrated in A'--A of Figure 8.

CHAPTER IV

DISCUSSION

Any conclusions as to patterns of distribution of amphibians and reptiles and their relation to biotic provinces are no better that the accuracy of the distributional maps used. Hagmeier and Stults (1964) concur with Cain (1947), Little (1951), and Kendeigh (1954) on the type of map best suited for a study of this type. The only accurate maps for studying biogeographic regions are dot maps based on specimen records. The distributional range maps constructed for this study were based on dot maps by Raun (unpublished). These dot maps were prepared from county records, as indicated by literature and museum references. A number of these records, obviously outside the expected range, are considered distributional isolates, misidentifications, or clerical errors. These were not taken into account in the construction of the distributional maps.

Inspection of a Texas county map reveals that with few exceptions all counties east of the Pecos River are about the same size. Furthermore, the several very small counties would aid in the accuracy of ranges derived from the dot maps. The distributional range maps constructed for this biogeographic evaluation are drawn along the county lines, which represent the most accurate means of observing distributional patterns of the current amphibian and reptile fauna of Texas.

The faunal similarity value map for amphibians and reptiles in Texas (Figure 9) is similar to but not exactly like the map constructed by Webb (1950) for the snakes only (Figure 10). The difference may be explained in several ways. A much greater number of species was considered in the present study. According to Hagmeier and Stults (1964), an ideal study of biogeographic regions would include all species of animals and plants. Thus, the biogeographic regions indicated by amphibians and reptiles only must be so designated. Furthermore, interpretation of biogeographic regions is subject to change until all species of plants and animals are included in the region under study. The distributional data upon which these new calculations are based are much more complete than that available to Webb, almost twenty years ago.

As noted in Chapter III, the Hagmeier and Stults (1964) method of province determinations may be interpreted in two ways. First, one may arrive at biogeographic regions of Texas similar to but not exactly like those constructed by the use of Webb's method (1950). The similarity between the results of these methods may be seen if Figure 11, the index of faunistic change method (Hagmeier and Stults, 1964), is compared with Figure 9, the similarity value method (Webb, 1950). The regions which have a similar amphibian and reptile fauna are shaded blue in both illustrations. This is a very significant comparison, because Hagmeier and Stults (1964), discount the similarity-value method of Webb (1950) as ineffective when used to delimit mammal areas in North America. Figure 12 is a composite map of the similarity

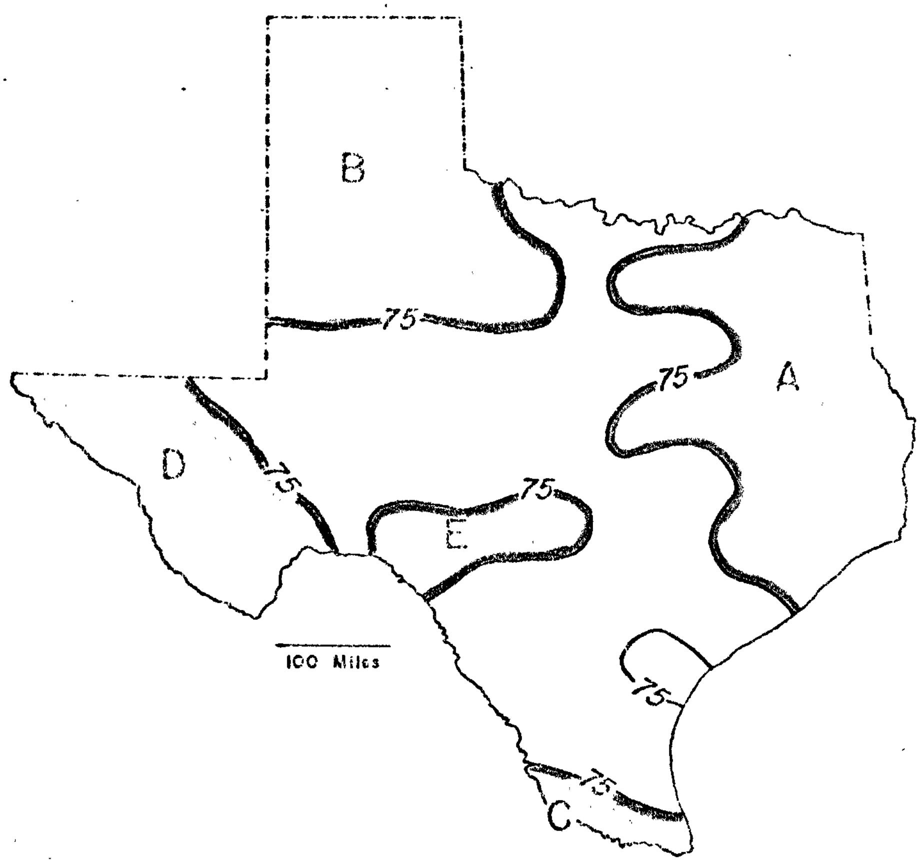

Fig. 9--Amphibian and Reptile Communities of Texas, by Webb (1950) method. Community regions indicated by shading: A-Eastern Forest Community, B-High Plains Community, C-Rio Grande Community, D-Trans-Pecos Community, and E-Balcones Community.

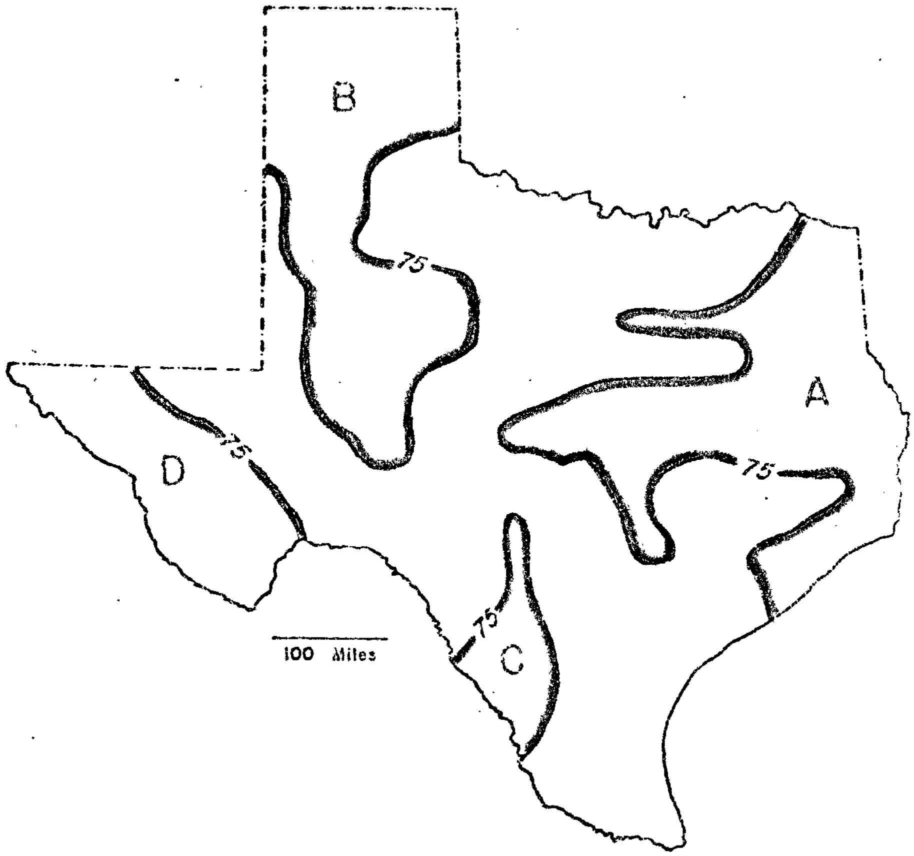

Fig. 10--Snake Communities of Texas, from Webb (1950). Community regions indicated by shading: A-Eastern Forest Community, B-High Plains Community, C-Rio Grande Community, and D-Trans-Pecos Community.

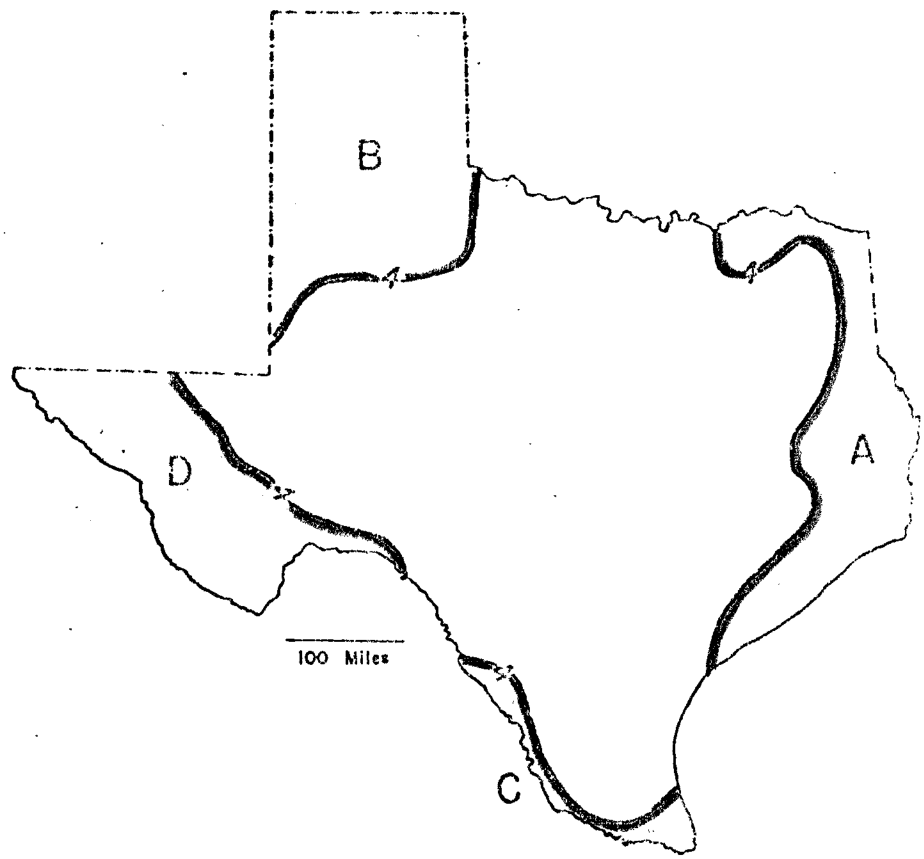

Fig. 11--Amphibian and Reptile Communities of Texas, by Hagmeier and Stults (1964) method. Community regions indicated by shading: A-Eastern Forest Community, B-High Plains Community, C-Rio Grande Community, and D-Trans-Pecos Community.

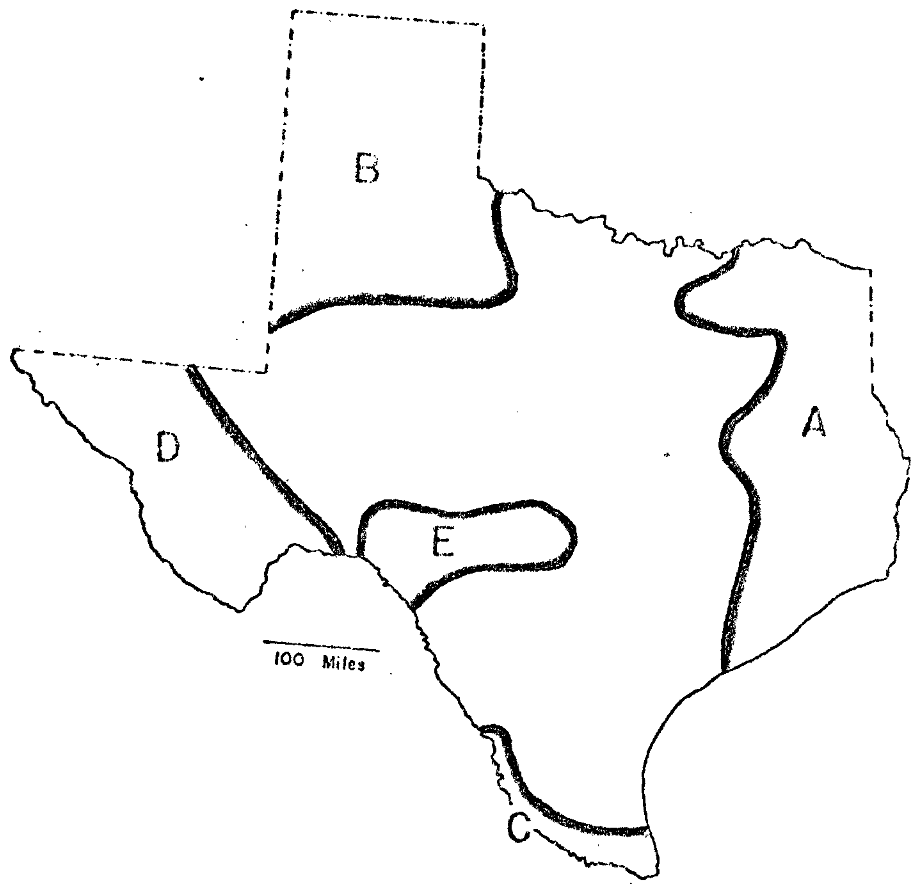

Fig. 12--Composite Map of Amphibian and Reptile Communities of Texas. Community regions indicated by shading: A-Eastern Forest Community, B-High Plains Community, C-Rio Grande Community, and D-Trans-Pecos Community.

value and the index of faunistic change maps of the biogeographic regions of Texas as determined by the amphibian and reptile fauna.

Second, one may delimit boundaries between biogeographic provinces in Texas by using the Hagmeier and Stults (1963) method. An amphibian and reptile biogeographic province may be constructed if areas of high index of faunistic change values are connected by a line (Figure 13). By this method five amphibian and reptile biogeographic provinces are delimited in Texas. There is a small heterogeneous area in northeastern Texas which is indicated by a short solid line.

It is difficult to interpret the index of faunistic change values. The numerical values are calculated objectively, whereas the most heterogeneous boundary is determined subjectively. According to Hagmeier and Stults (1964), there are 24 mammal provinces in North America, of which 6 have boundaries occurring within Texas. Hagmeier (1966) revaluated these provinces, changing the number of provinces to 35 in North America and 7 in Texas. Hagmeier (1966) indicated that the same numerical index of faunistic change valuations are used in this second interpretation. Furthermore, it is difficult to compare the resultant biogeographic mammal provinces developed in the two papers (Figures 14 and 15).

The amphibian and reptile biogeographic provinces of Texas, as developed using the index of faunistic change values (Figure 13), correspond very closely to the biotic provinces of Texas (Figure 16) as determined by Blair (1950). Accordingly, the amphibian and reptile biogeographic provinces of Texas are named according to Blair (1950), with two modifications. First, the eastern province is termed

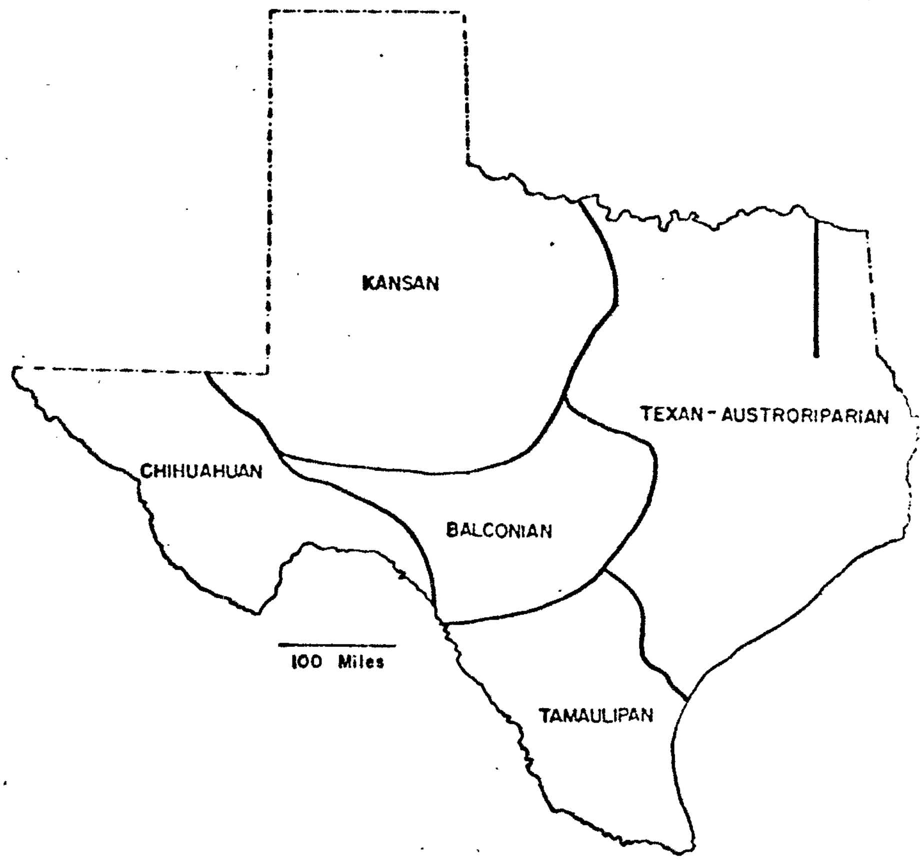

Fig. 13--Amphibian and Reptile Biogeographic Provinces of Texas.

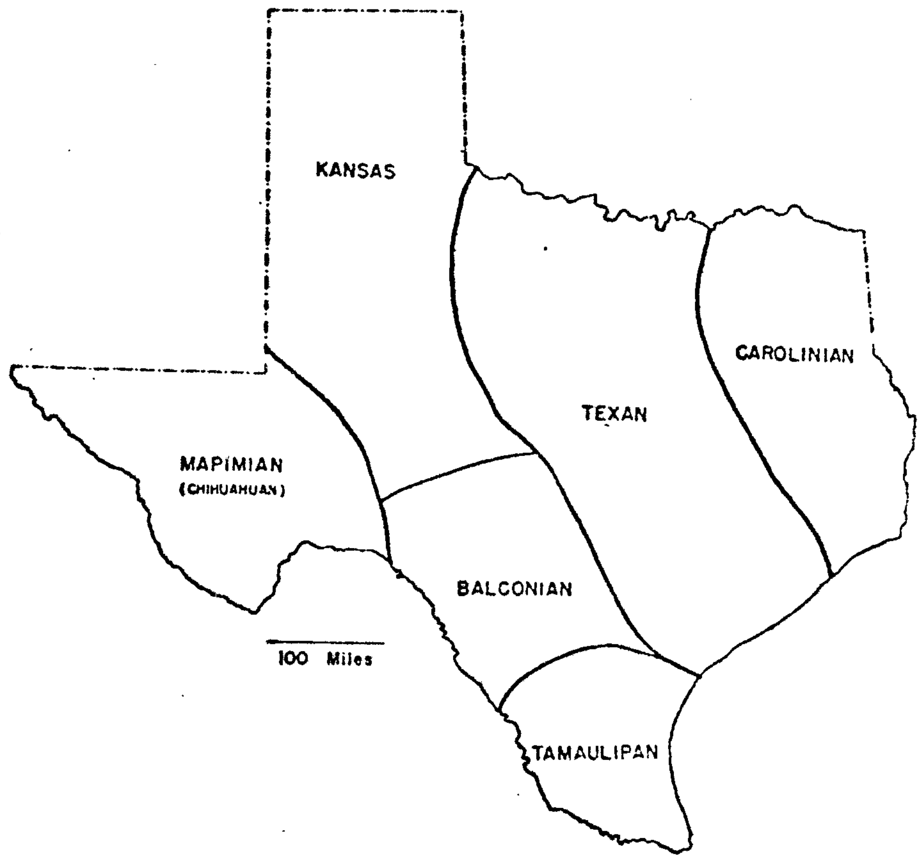

Fig. 14--Mammal Biogeographic Provinces of Texas, from Hagmeier and Stults (1964).

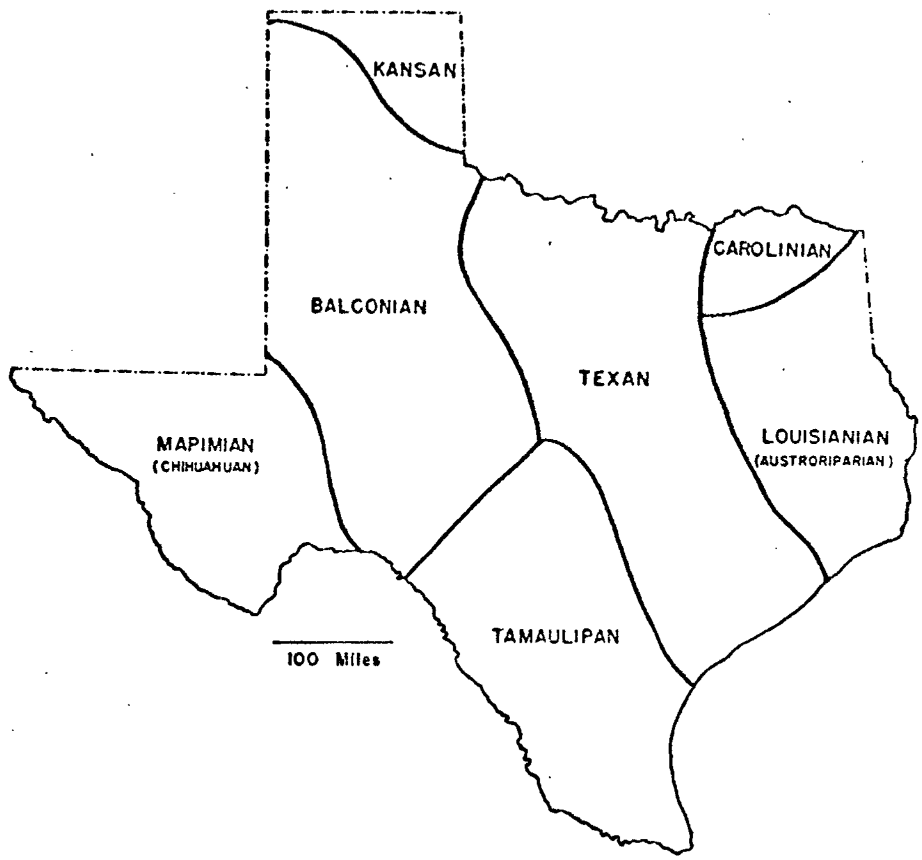

Fig. 15--Mammal Biogeographic Provinces of Texas, from Hagmeier (1966).

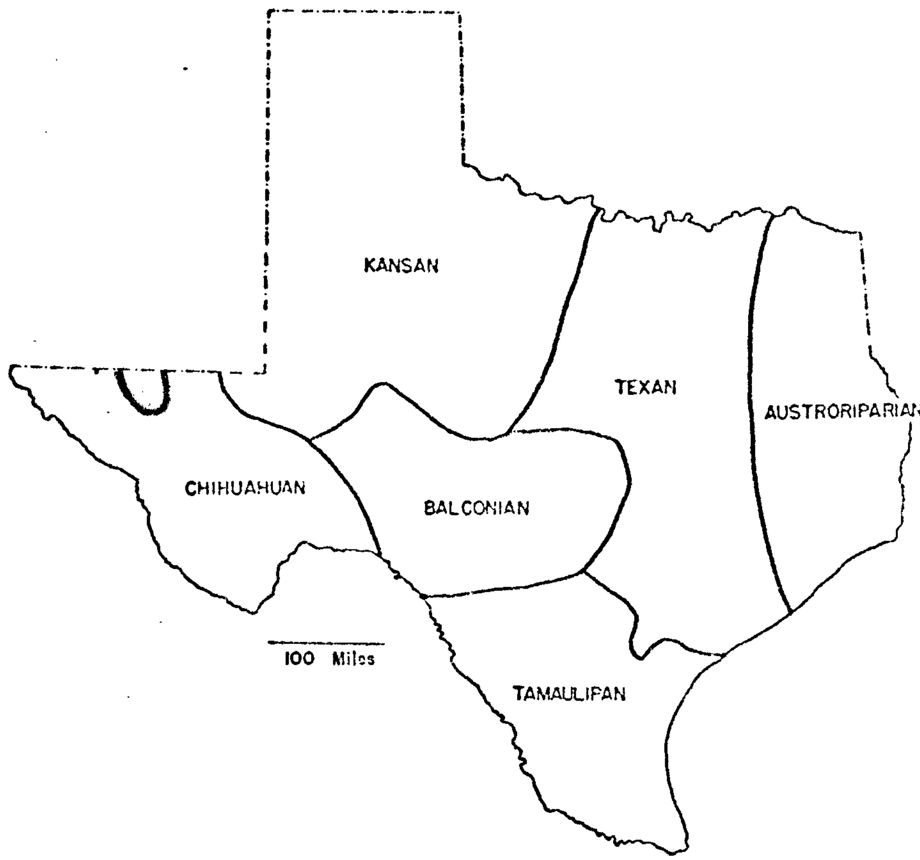

Fig. 16--Biotic Provinces of Texas, from Blair (1950). Navahoian indicated by shading.

the Texan-Austroriparian Province, as it includes both biotic provinces. Second, the Navahoian Province (shaded blue in Figure 16) is not apparent in the index of faunistic change analysis of the amphibians and reptiles.

The biotic provinces recognized by Blair (1950) within Texas are characterized as follows: (1) The Austroriparian Province extends into East Texas from the coastal plains of the Gulf of Mexico to the Ouachita Mountains of Oklahoma. The plants and animals of this province are mainly forms which may be found westward from the coastal plains to the Atlantic. (2) The Texan Province borders the Austroriparian Province in the eastern part of the state. This province is a broad ecotone between the Austroriparian forest and the semiarid grasslands to the west. It is characterized by the interdigitation of forest and grassland associations and species. (3) The Tamaulipan Province is composed of the Gulf coastal plain south of the Balcones Escarpment and west of the boundary between pedalfer (found in areas having an annual rainfall of 25 inches or more) and pedocal soils. This province is characterized by an intermixture of Neotropical species, Austroriparian species, and southwestern desert species. (4) The Chihuahuan Province includes all of Trans-Pecos Texas, except for the Guadalupe Mountains. The fauna of this province is (for the most part) widely distributed in the mountains and deserts of southwestern North America. (5) The Navahoian Province extends into Texas in the Guadalupe Mountains. The fauna of this province bears a close relationship to those of the Chihuahuan Province; however, several high-elevation species occur only within the Navahoian Province. (6) The Kansan Province includes the panhandle and the plains to the east of the escarpment of the high plains. The plants and animals are primarily grassland forms; however, some Austroriparian species extend along wooded stream valleys into the eastern part of the province. (7) The Balconian Province includes the Edwards Plateau, the Lampasas Cut Plains, and the Central Mineral Region. The fauna of the province are basically a mixture of Austroriparian, Tamaulipan, Chihuahuan, and Kansan Province species. Also, several species are endemic to the Balconian Province (Blair, 1950).

The graphic analysis was prepared in an attempt to illustrate the actual range limits of species across the state, and to compare these with the statistical analysis. It is the distribution of animals which is significant, not the distribution of numerical values. The graphic analysis substantiates the fact that all biotic provinces, according to Blair (1950), are approximately equal to the amphibian and reptile biogeographic provinces, with one exception. The Texan Biotic Province is not a valid amphibian and reptile province in Texas. Furthermore, the species' stair-step effect from the east across the Texan Biotic Province substantiates this area's similarity to that of the east. For this reason, the Texan and the Austroriparian Biotic Provinces are collectively termed the amphibian and reptile Texan-Austroriparian Province.

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